Q 15: Quantengase (Gitter I)

Zeit: Dienstag 14:00–16:00 Raum: 1C

Q 15.1 Di 14:00 1C

Bogoliubov *vs.* chaotic energy spectrum for Bose atoms in optical lattices — •Andrey Kolovsky — Kirensky Institute of Physics, 660036 Krasnoyarsk, Russia

Recent experiments with cold bosonic atoms in optical lattices has renewed the theoretical studies of the Bose-Hubbard model, which constitutes one of the fundamental Hamiltonians in the condensed matter theory. The number of phenomena, discussed in the frame of this model, is so diverse that sometimes it is difficult to see any link between them. In particular, this concerns the phenomena of superfluidity and Quantum Chaos. Indeed, the former phenomenon assumes the regular phononlike excitation spectrum, described by the Bogoliubov theory, while the latter phenomenon implies a highly irregular excitation spectrum, described by the random matrix theory. This seeming contradiction is resolved by noting that these two spectra refer to different characteristic energies of the system. In the talk I shall explain of how the regular Bogoliubov spectrum of the Bose-Hubbard system evolves into an irregular one as the system energy is increased. A manifestation of this transition for the excitation dynamics of the superfluid state of cold atoms in optical lattices is discussed as well [1].

[1] A. R. Kolovsky, Phys. Rev. Lett. **99**, 020401 (2007); Phys. Rev. E **76**, 026207 (2007).

Q 15.2 Di 14:15 1C

Many-body Wannier-Stark dynamics — •Patrick Plötz[1,2] and Sandro Wimberger[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philsophenweg 19, 69120 Heidelberg — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, 69120 Heidelberg

Interacting bosons in a one-dimensional optical lattice are studied in the presence of an additional and tunable tilting force in the strongly-correlated many-particle regime. We use a multi-band Bose-Hubbard model to describe this many-body Wannier-Stark problem. Tomadin *et al.* [Phys. Rev. Lett. **98**, 130402 (2007)] perturbatively included the first excited energy band on top of the widely used single band approximation, and found clear signatures of complex quantum dynamics in the interband tunneling rates. We investigate, in turn, the dynamics of a complete two-band model non-perturbatively. The dominant coupling channels between the bands are found for a realization with ultracold atoms. Our model allows us to study the vertical transport in energy space as well as the horizontal quantum transport along the lattice and their interdependence.

Q 15.3 Di 14:30 1C

Bloch oscillations and Landau-Zener tunneling of interacting ultracold atoms — •Ghazal Tayebirad and Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg

A series of recent experiments measured the impact of atom-atom interactions on Bloch oscillations [1,2] and on Landau-Zener interband tunneling [3] of ultracold atoms in a tilted periodic (washboard) potential. We investigate the effect of interactions in the mean-field regime on these dynamical processes. Moreover, we discuss possibilities of controlling quantum transport in the interacting Wannier-Stark system by time-dependent and spatially inhomogeneous potentials.

[1] M. Fattori *et al.*, arXiv:0710.5031.
[2] M. Gustavsson *et al.*, arXiv:0710.5083.
[3] C. Sias *et al.*, Phys. Rev. Lett. **98**, 120403 (2007).

Q 15.4 Di 14:45 1C

Phase Diagram of Spin-1 Bosons in Optical Lattice at Non-Zero Temperature — •Matthias Ohliger[1] and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

We extend previous zero-temperature mean-field studies [1,2] for the location of the superfluid-Mott insulator transition of spin-1 bosons in an optical lattice to finite temperatures. We find that the phase boundary changes continuously with the magnetization of the system and that a complete magnetization reproduces the phase diagram of spin-0 bosons [3,4]. For an antiferromagnetic interaction, however, the zero-temperature limit of our phase diagram deviates significantly from the zero-temperature mean-field studies [1,2], where a degenerate perturbation theory is applied for an odd number of bosons per site.

[1] S. Tsuchiya, S. Kurihara, and T. Kimura, Phys. Rev. A **70**, 043628 (2004)
[2] T. Kimura, S. Tsuchiya, M. Yamashita, and S. Kurihara, J. Phys. Soc. Japan **75**, 074601 (2006)
[3] P. Buonsante and A. Vezzani, Phys. Rev. A **70**, 033608 (2004).
[4] K.V. Krutitsky, A. Pelster, and R. Graham, New J. Phys. **8**, 187 (2006).

Q 15.5 Di 15:00 1C

Diagrammatic Calculation of Finite-Temperature Properties of the Bose-Hubbard Model — Henrik Enoksen[1], Alexander Hoffmann[2], •Matthias Ohliger[3], and Axel Pelster[4] — [1]Department of Physics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway — [2]Arnold Sommerfeld Center for Theoretical Physics, Theresienstr. 37, Department Physik, Universität München, 80333 München, Germany — [3]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [4]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

Following an approach first worked out by Metzner in the context of electrons in conductors [1], we use a diagrammatic hopping expansion to calculate finite-temperature Green's functions for the Bose-Hubbard model which describes bosons in an optical lattice. This allows us to reconstruct in a qualitative way the time-of-flight absorption pictures, which are taken after the optical lattice is switched off. Furthermore, the technique makes summations of subsets of diagrams possible, leading to non-perturbative results for locating the boundary between the superfluid and the Mott phase for finite temperatures. Whereas the first-order calculation reproduces the seminal mean-field result, the second order goes beyond and shifts the phase boundary in the immediate vicinity of the critical parameters determined by Monte-Carlo simulations of the Bose-Hubbard model.

[1] W. Metzner, Phys. Rev. B **43**, 8549 (1993)

Q 15.6 Di 15:15 1C

Quantum Corrections of Mean-Field Phase Diagram for Bosons in Lattices — •Francisco Ednilson Alves dos Santos[1] and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

We improve the zero-temperature mean-field calculations for bosons in optical lattices by systematically working out the effect of quantum corrections. To this end we decompose the underlying nonlocal Bose-Hubbard Hamiltonian into the local mean-field Hamiltonian and treat the difference between them perturbatively. Using a diagrammatic technique, we calculate the ground-state energy up to second order in the quantum corrections. Therein, we interpret the order parameter ψ as a variational parameter, which is determined from optimizing the ground-state energy. With this analytical approach we obtain for arbitrary spatial dimension an improved boundary between Mott insulator and superfluid phase in accordance with previous high-precision results from quantum Monte-Carlo simulations.

Q 15.7 Di 15:30 1C

AC-induced superfluidity — •André Eckardt and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, 26111 Oldenburg

In previous work we have shown that it should be possible to coherently control the transition from a superfluid to a Mott insulator in the Bose-Hubbard model by an oscillating force through an effective modification of the tunneling matrix element [Eckardt et al., PRL 95, 260404 (2005)]. The effective tunnel modification has recently been observed experimentally by the Arimondo group in Pisa, without notable loss of coherence caused by the drive [Lignier et al., cond-mat/0707.0403 (2007)]. In this talk we will consider a Bose-Hubbard system that is subjected to a static potential tilt such that tunneling is strongly suppressed due to the localization of the Wannier-Stark states. We show that tunneling can be restored partially in a coherent way by resonantly driving the system at high frequencies (a few kHz for a typical experiment with Alkali atoms in an optical lattice). For integer filling, the interplay between interparticle repulsion and this kind of "photon"-assisted tunneling should give rise to a Mott-like transition, with (quasi) long-range order (i.e. superfluidity) being established by switching on the AC-drive [Eckardt & Holthaus, EPL 80, 50004 (2007)]. It is also possible to control the sign of the effective tunneling matrix element by varying the amplitude of the drive. We argue that an adiabatic passage of the system's ground state through such a sign change is a many-body effect that relies on the existence of a Mott-insulator phase.

Q 15.8 Di 15:45 1C

Ultracold bosons in optical superlattices with and without disorder: A numerical approach — •Dominik Muth, Alexander Mering, and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern

The time-evolving block decimation algorithm (TEBD) for one-dimensional systems and its modification for infinite size systems (iTEBD) can be used to determine the ground state for various Hamiltonians. We apply this method to determine the superfluid to Mott-insulator phase transition for a Bose-Hubbard model with a superlattice. While for small hopping parameter J the loophole-shaped insulator domains, derived by a mean-field approach [1], fit quite well to our numerical results, the results differ for large hopping as expected. Adding disorder to the system, we show that the loophole domains detach from the J=0 axis, creating insulating islands surrounded by a Bose-glass phase.

[1] P. Buonsante, A. Vezzani - Phys. Rev. A 72, 013614 (2005)